Growth and Yield of Plantain in High Planting Density under Nitrogen and Potassium fertilizers on Ferralsol of Humid Forest

Toward a method of fertilization in continue cropping in Côte d'Ivoire

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ABSTRACT

It is necessary to adopt high planting density of plantain (*Musa sp*.) for resorbing the seasonal deficit of the local market supplying while compulsory fertilizer recommendation only exist for low planting density (1667 plants ha^{-1}) in Côte d'Ivoire. Five rates of each of the nitrogen-N (200, 240, 260, 280 and 300 $kgha^{-1}$) and potassium-K (548, 658, 712, 767 and 822 $kgha^{-1}$) were partially combined adding 30 gP and 53 gCa per plant before applying during two (2012 – 2014) cropping seasons of plantain variety Corne 1 (2500 plants/ha). The girth of pseudo stem and the number of functional leaves were likely interfering with the bunch weight which response was limited to the rates of 240 $kgNha^{-1}$ and 658 $kgKha^{-1}$. Further improvement is expected when enhancing the efficiency of potassium nutrition by adjusting P-rate to 37.5 g/plant and the irrigation (> 20 mm) in order to induce greater response to N×K fertilizer.

Key-words: High planting density, nitrogen and potassium fertilizers, plantain, sustainability of agrosystem, Côte d'Ivoire

1-Introduction

Plantain (*Musa* sp.) is of major socioeconomic importance for central and West african populations. In these regions, plantain has significant contribution for food security and rural development (Nkendah and Akyeampong, 2003; Orellama *et al.*, 2002). In Côte d'Ivoire, plantain is a staple diet of many people while contributing to household income diversification. However, its production is characterized by a low planting density of about 1667 plants/ha exclusively during the rainy season resulting a seasonal shortage. In fact, the supplying is alternatively abundant from October to April and deficient from May to September (Kobenan, 2009). Therefore, the production system needs improvement.

It is reported that plantain can continue growing during a dry season requiring minimum irrigation especially because of water holding by the rhizome and the pseudo stem (Nelson *et al.*, 2006). Hence, the development of off-season cropping of plantain may have response to seasonal shortage especially, when applying high planting density as observed in many other countries (Chaudhuri and Baruah, 2010, N'guetta *et al.*, 2015). In fact, the high planting density can control soil moisture loss and weed occurrence in the field because of the important canopy (Singh *et al.*, 2012).

However, the high planting density may increase soil nutrient exportation as well as moisture requirement of crop (Germeau, 2006; Husameldin and Mohammed, 2014). The low inherent soil fertility of sub-Saharan countries (FAO, 2003), may accounts for major constraint against the sustainability of such practice unless restoring adequately the soil chemical fertility. In this line, mineral fertilizer was proposed to built-up the soil nutrient loss and controlling mineral deficiency in agrosystems (Bationo *et al.*, 2006): Nitrogen (N) and potassium (K) were especially recommended for plantain production (Patil and Shinde, 2013) contrasting with phosphorus (P) requirement (Thippesha *et al*., 2008). Well, Côte d'Ivoire belong to the tropical humid zone characterized by soil annual loss of 54 kg/ha N, 20 kg/ha P_2O_5 and 56 kg/ha K_2O_5 under cropping (Stoorvogel and Smaling, 1990) not including the loss of 0,87g N/kg and 0,45g K/kg under secondary vegetation of humid forest zone (Koné *et al.*, 2004a). Therefore, fertilizers are required for adopting high plantain density of plantain (> 1667 plants/ha) in Côte d'Ivoire, especially for N and K supplying.

The existing recommendations are only for the density of 1667 plants/ha (N'guessan *et al.*, 1993) while Esquinosa and Belalcázar (2000) underlined the yield variability according to the planting density for single rates of N and K. Regarding to agroecology criteria of agricultural land fertilization (Wenhua, 2001), it is advocated to characterized plantain response to N and K when applying high density in the prevailing cropping areas in Côte d'Ivoire.

Therefore, the current study is volunteer to identify the rates of N and K for optimizing the production of plantain named Corne 1 (*Musa, AAB*) applying 2500 plants/ha in density under irrigation during off-season.

2. Method and materials

2.1. Studied zone

The study was conducted in the field of *Association pour le Développement des Cultures Vervieres Intensives (ADCVI)* around the locality of Tiassalé (5°56'N; 4°51'O; 29 m) in the South of Côte d'Ivoire. It is a secondary forest zone of tropical humid climate characterized by a bimodal rainfall (1200 mm) pattern. The annual rain fall amount was 1050 in 2013 and 1868 mm in 2014. The temperature was fluctuating between 25˚C and 30˚C coupled with a hygroscopy over 70% (Goula, 2005). The experiment was preceded by vegetable and cassava successively. The soil is *Ferrallitique typique remanié* (CPCS, 1967) equivalent of Plinthic

Ferralsol (FAO, 2006) with a silt sandy texture in 0 – 40 cm depth. Soil chemical contents in 0 – 20 cm and 20 – 40 cm depths are presented in the table 1.

Table 1: Experiment site chemical contents in 0 – 20 cm and 20 – 40 cm depths of soil

Parameters	Horizon 0-20 cm	Horizon 20-40 cm
Carbon (gkg^{-1})	1.54	0.9
Total nitrogen (gkg^{-1})	0.15	0.08
C/N	10.26	11.25
Available phosphorus-Olsen ($mgkg^{-1}$)	11	10
Calcium ($cmolkg^{-1}$)	2.45	1.99
Potassium ($cmolkg^{-1}$)	0.23	0.15
Magnesium ($cmolkg^{-1}$)	0.69	1.85
Ca : Mg	4 :1	1 :1
Mg : K	3 :1	10 :1
Sodium ($cmolkg^{-1}$)	0.04	0.05
ECC ($cmolkg^{-1}$)	6.7	6.2
K/ECC (%)	3	2
pH_{water}	6.4	6.2

2.2. Genetic material

The studied material was a vivo plant locally realized by CNRA (*Centre National de Recherche Agronomique*) and named Corne 1. This cultivar is popular in the studied zone of Côte d'Ivoire (N'guessan *et al.*, 1993). It is appreciated by its characteristics of beg and long fingers of the fruits. The cropping cycle is 11 months with a potential yield of 25 tha^{-1} for a density of 1667 plants/ha on research station. However, it is sensitive to dark brown and yellow Stigatoka diseases as cercosporiose injury as well as to nematode effect.

2.3. Experimental design and the trial implementation

A fallow land of 4620 m^2 previously occupied by cassava was manually cleaned and tilled for agronomic trial repeated in 2012 and 2013. Both experiments were continuously laid out from

September 2012 to September 2013 and from September 2013 to October 2014 respectively. The planting was repeated for each experiment and the second planting was done after the first harvest.

The experimental design was a randomized complete bloc with four replications. The recommended rates of N and K under the practiced planting density (1667 plants/ha) were combined for the check treatment (control) and further increased by 1.2; 1.3; 1.4 and 1.5 times in four other treatments of the trial which included a total of five by replication:

- T1 : 200 kg (N) + 548 kg (K) /ha as control
- T2 : 240 kg (N) + 658 kg (K) /ha (T1 × 1.2)
- T3 : 260 kg (N) + 712 kg (K) /ha (T1 × 1.3)
- T4 : 280 kg (N) + 767 kg (K) /ha (T1 × 1.4)
- T5 : 300 kg (N) + 822 kg (K) /ha (T1 × 1.5)

N and K were supplied as urea (46% N) and potassium chloride (60% K_2O). Two months after planting, the total amounts of N and K were splited equitably for 8 months to be applied in around a plant under the canopy corona. Additional rates of 30 g of P and 53 g of Ca were previously applied as basal fertilizer per plant indifferently to treatment. Nursery plants were planted in a hole of 30 × 30 × 30 cm and spaced by 3 m × 2 m apart in a density of 2500 plants/ha. A treatment plot was characterized by 56 plants in 163.2 m^2 (9.6 m × 17 m) and a replication was accounting for 20 microplots. The four replications were spaced by 3 m apart for 1120 total microplots.

2.4. Trial management

Monthly and manual weeding was done when necessary after herbicide (Glyphosate) application. Benco plus, a commercial name of a fungicide composed of chlorithalonil and carbendazine was applied from 5 months after planting all along the trial for the control of cercosporiose coupling this practice to weekly cutting of necrotic leaf. Rugby, a commercial name of nematicide composed of cadusafos was also applied threes at 30 g/plant during the second season of cropping (2nd trial). Five times sprinkler irrigation (4 mm/day) were applied except after a rainfall of more than 5 mm.

2.5. Data collection

Thirty (30) plants of plantain were observed at flowering and maturity stages in each microplot of treatment for different parameters assessment:

- **Vegetative stage parameters**: plant height (cm) was measured from the soil surface to the ramification observed between the youngest leaf and the inflorescence. The girth of the pseudo stem (cm) was also measured 1m above ground. The number of functional leaves (about 2/3 canopy) and total leaves were counted. Moreover, the durations (days) until the flowering stage (IPF) and the harvest one (IPR) were determined.

- **Reproduction parameters**: the numbers of hands and fingers per plant were counted as well as the gird and intern longer of median finger of the 4th hand. Also, the mean weight of bunch was recorded.

2.6. Soil sampling and analysis

Before the study, two composite samples were taken in 0 – 20 cm and 20 – 40 cm depths of soil. Subsamples were taken in the four corners and the centre of the studied area using hand augur. The samples were dried, grounded and sieved (2mm) before processing the analysis. Total nitrogen (N) content of soil was determined by Kjeldahl method of cold oxidation and that Olsen was used for available phosphorus (P) content measurement. Walkley and Black method was for organic carbon (C) content determination while exchangeable cations were extracted by ammonium acetate as well as done for determining soil Exchangeable Cation Capacity (ECC): K and Na contents were then identified by flam photometry unlike for Ca and Mg identified by Atomic Absorption of Spectrometry. The soil pH was determined for a ratio soil/water of 1/2.5 using glass electrode.

2.7. Data statistical analysis

Statistical analyses were done using the package of SAS version 9.0. Analyses of variances (ANOVA) were performed and the mean values were compared by least significant difference (lsd) test. The relationships between studied parameters were explored by Pearson correlation analysis. Results of analyses account for $\alpha = 0.05$.

3. Results

3.1. Treatment effects on vegetative growth parameters

There are significant probabilities (P <0.0001) of the treatment effects on the growth parameters (height and pseudo stem girth) during the first cropping cycle. The treatment T1 has the lowest mean values of height (332.2 cm) and girth (52.4 cm) as compared to the other treatments (Table 2). In turn, no significant difference accounts for the mean values of height according to the treatments T2, T3, T4 and T5 while a relative increasing trend of the girth is observed as far as the treatment is increased although, these mean values are statistically similar.

This result is confirmed (P<0.0001 and P=0.0014) during the second cropping cycle, showing reduced values of plant height (329.6 cm) and pseudo stem girth (50.6 cm) in T1 though, similar values of plant height account for T4 and T5 likely for the girth recorded in T2, T3, T4 and T5. Roughly, there is significantly (P <0.05) reducing trend of pseudo stem girth from the

1rst to the 2nd cropping cycle while the plant height remains stable (Table 2). The number of the total leaves and that of the functional leaves (Table 3) are significantly (*P* = 0.0081 and *P* =0.0015) observed during the first cropping cycle. The lowest values of these parameters are observed for T1 during both cropping cycles. Except the lowest value (32) of total leaves (FE) of T2 during the first cropping cycle, this treatment is among the best during both cycles for almost the studied parameters while the treatment T5 has lowest values of functional leaves (FF) indifferently to the cropping cycles.

Table 2: Plantain banana height and pseudo stem girth at flowering stage

	Height (cm)		Girth (cm)	
Treatement	Cycle 1	Cycle 2	Cycle 1	Cycle 2
T1	332.2 b**A**	329.6 c**A**	52.4 c**A**	50.6 b**B**
T2	352.7 a**A**	349.7 b**A**	55.2 b**A**	52.2 a**B**
T3	353.6 a**A**	352.1 ab**A**	55.6 ab**A**	53 a**B**
T4	355.1 a**A**	354.9 a**A**	55.8ab**A**	53 a**B**
T5	355.8 a**A**	355.3 a**A**	56.3 a**A**	53.1 a**B**
GM	349.9	348.3	55	52.4
CV (%)	0.73	0.69	0.89	1.46
P>F	<0.0001	<0.0001	<0.0001	0.0014

The letters a, b and c are indicating the mean values with significant difference in column for α= 0.05 as done A and B in line;

No significant difference is observed between the mean values of IPF and IPR respectively according to the treatments while, they are significantly decreased from the first to the second cropping cycle though, no significant probability (*P* > 0.05) is often observed. Definitively, there is increase of the leaf numbers according to cropping cycle coupled with shorter duration of crop physiological activities (IPF and IPR) when excluding the treatment T2.

3.2. Effect of treatments on fruit production

There is no significant difference between the mean values of the numbers of hands (7 – 8) and fingers (34 – 35) of plantain according to the treatments during respective cycles (Table 4). Similar result is observed for the inner length of the median finger of the fourth hand (18 – 20 cm). In turn, there is significantly (P <0.05) a difference between the mean values of median finger girth (12.2 – 13.8 cm) during each of the cropping cycles: lowest values (12.2 – 12.4 cm) account for treatment T1 contrasting with the other treatments which have statistically similar values. In the same line, lowest mean values of bunch weight (12.9 kg) are significantly (P = 0.0026) accounting for T1 with significant difference comparing to the other treatments during the first cropping season (Figure 1). In spite of the decreasing trend of bunch weight (12.5 kg – 14.5 kg/bunch) according to the increasing order of the other treatments (T2, T3, T4 and T5), no significant difference is recorded likely between both the cropping cycles.

Table 3 : Mean values of the total leaves (FE) and functional leaves (FF) numbers as well as the durations until flowering (IPF) and harvest (IPR) periods

	FE/plant		**FF/plant**		**IPF (Days)**		**IPR (Days)**	
Treatment	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 1	Cycle 2
T1	-	34 b	10 c**B**	11 c**A**	280 a**A**	272 a**B**	354 a**A**	346 a**B**
T2	32 b**B**	35 a**A**	13 a**A**	13 a**A**	272 a**A**	268 a**A**	345 a**A**	341 a**A**
T3	35 a**A**	35 a**A**	12 ab**A**	13 ab**A**	274 a**A**	265 a**B**	347 a**A**	338 a**B**
T4	35 a**A**	36 a**A**	12 ab**A**	12 ab**A**	277 a**A**	270 a**B**	351 a**A**	342 a**B**
T5	36 a**A**	36 a**A**	11 b**B**	12 b**A**	274 a**A**	268 a**B**	347 a**A**	340 a**B**
GM.	34	35	12	12	276	269	349	341
CV (%)	3.69	2.67	5.29	3.64	1.36	1.35	1.28	1.22
P>F	0.0081	0.0084	0.0015	0.0013	0.0576	0.1421	0.1073	0.1456

The letters a, b and c are indicating mean values with significant difference in column for α=0,05 as well as done A and B in line.

Table 4 : Yield parameters of plantain Corne 1 according to the treatments

	Hand number		Finger number		Inner length (cm) of finger		Girth (cm) of the median finger	
Treatment	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 1	Cycle 2
T1	8 a**A**	7 a**A**	35 a**A**	36 a**A**	18.3 a**B**	19.4 a**A**	12.2 b**A**	12.4 b**A**
T2	8 a**A**	7 a**A**	36 a**A**	36 a**A**	19.1 a**A**	20.2 a**A**	14.1 a**A**	13.8 a**A**
T3	8 a**A**	8 a**A**	35 a**A**	35 a**A**	18.6 a**A**	19.6 a**A**	13.7 a**A**	13.5 a**A**
T4	7 a**B**	7 a**A**	34 a**B**	35 a**A**	19.2 a**A**	19.6 a**A**	13.6 a**A**	13.4 a**A**
T5	7 a**B**	8 a**A**	35 a**A**	36 a**A**	18.4 a**A**	19.5 a**A**	13.6 a**A**	13.4 a**A**
GM	8	7	35	36	18.7	19.7	13.4	13.3
CV (%)	2.44	3.25	1.79	2.17	6.89	3.40	3.20	2.57
P>F	0.2011	0.1139	0.0559	0.3203	0.7676	0.1656	0.0002	0.0003

Letters a, b and c are indicating the mean values with significant difference in the column for α=0,05 as done A and B in the line;

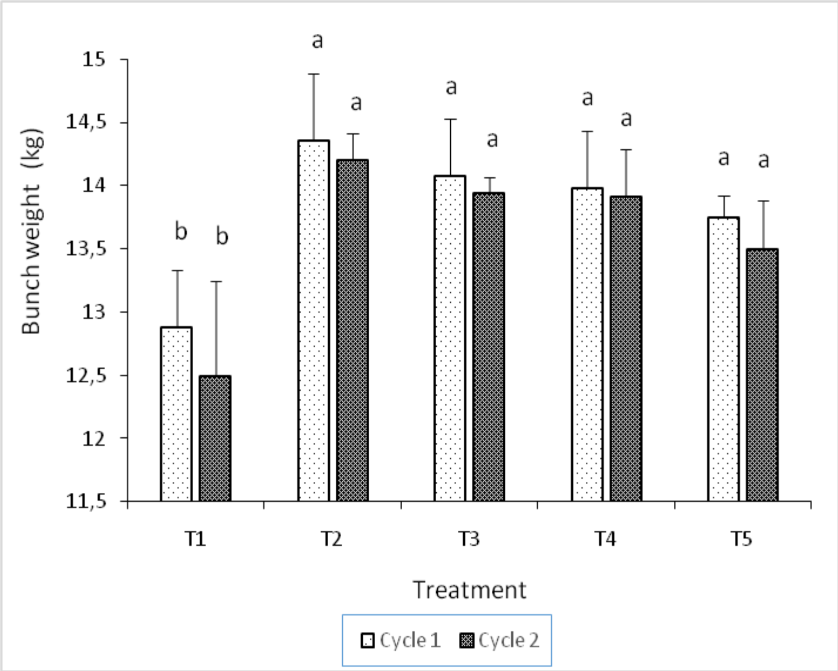

Figure 1: Plantain bunch weight during the cycle 1 and cycle 2 according to the treatments ($P_{cycle\ 1} = 0.0026$; $P_{cycle\ 2} = 0.0004$)

3.3. Relation between bunch weight and the other studied parameters

There is significant ($P < 0.05$) and positive correlation (R = 0.89) between plant height and bunch weight during the first cropping season (Table 5). Similar result is also observed for the number of functional leaves (FF) indifferently to the cropping cycles. In turn, significant negative correlation value (R = -0.98) is observed for the total leaves number (FE) only during the first cropping season likely for the duration until the flowering period (IPF). No significant correlation is observed between the bunch weight and the duration until the harvest period (IPR).

Table 5: Relation between the bunch weight and the other studied parameters

		R		P>|r|	
		1rstCycle	2ndCycle	1rstCycle	2ndCycle
Bunch Weight	Height	0,89	0,83	*	Ns
	P. Girth	0,81	0,76	Ns	*
	FE	-0,98	0,57	**	Ns
	FF	0,99	0,98	**	**
	IPF	-0,88	-0,67	*	Ns
	IPR	-0,85	-0,79	Ns	Ns

P. Girth : Plant girth ; FE : Number of total leaves; FF : Number of functional leaves;
Ns : non significant ; * : significant ; ** : highly significant;

4. Discussion

4.1. Agromorphological responses and impact on yield

There was significant difference between the mean values of plant height following the increasing order of treatments, thought, the treatments T3, T4 and T5 had similar values during each of the cropping cycles. The same trend was also observed for the circumference of pseudo stem. These results are the consequences of the plant metabolisms depending to N and K nutrition respectively: nitrogen and potassium are playing an important role in cells elongation and growth (Brar and Imas, 2009; Sushma *et al*., 2012) enhancing the growth in height and radial of the plantain pseudo stem. However, these parameters had differently reacted to the cropping cycle effect with a reduction of the girth during the second cycle whatever the treatment, and a positive high correlation with the bunch weight was observed in different cropping cycle. It is likely that the increasing of height may impair that of the radial growth and vice versa, especially, when influencing the bunch weight and vegetative vigor properties of the plant (Berchoux and Lecoustre, 1986) may accounts for these results. Nevertheless, the mean value of girth (50 – 56 cm) recorded during the current study should be improved by more sound fertilizer strategy as far as possible regarding the result observed (55 – 60 cm) elsewhere (Al-hastin and Al-Yahya, 2009).

The numbers of leaves (FE and FF) were also impacted by the increasing rates of fertilizer remaining constant across cycles when contrasting with the durations until the flowering and harvest periods. In fact, the vegetative development characterized by the growth rate and leaf area index is sensitive to fertilizer when the soil nutrient deficiencies are observed for plant nutrition (Patil and Shinde, 2013; Kumar *et al*., 2014) especially, under high nutrient requirement when increasing planting density. Therefore, lowest value of total leaves number (FE) was observed for the treatment T1 as control and usually recommended for a lower planting density than that of the current study.

More deepen analysis underlined highest consistent relation between the number of functional leaves (FF) and bunch weight by positive high correlations (0.99 and 0.98) during both cycles. Indeed, similar observations were done by other workers (N'guessan *et al.*, 2000; Blomme *et al*., 2001) and the fruit filling was likely influenced by the functional leaves because of their photosynthesis activity releasing carbohydrates (Zhu *et al*., 2008) which were translocated in reproductive organ. This metabolism was more pronounced in the treatment T2 regarding to the highest fruit girth.

The current results emphasizes the potential of the studied cultivar Corne 1 with 10 – 13/plant as functional leaf number and 11 – 14 kg/plant as bunch weight against respectively 7 – 9 kg/plant and 3 – 7 kg/plant for the variety Agbagba (3m × 3m) cropped in Nigeria (Akinyemi *et al.*, 2008). Consequently, Corne 1 is deemed suitable for high planting density and the treatment T2 can be of interest for investigation of improved agronomic practices.

4.2. Limited response to fertilizer

Except the significant differences observed between the mean values of almost the studied parameters for the treatment T1 and that of the others, the increase of N and K rates has no more impacted the vegetative and reproductive development of plantain during the experiment. Meanwhile, N and K rates were respectively increased from 200 $kgha^{-1}$ to 300 $kgha^{-1}$ and from 548 $kgha^{-1}$ to 822 $kgha^{-1}$ indicating the treatment T2 (240 $kgNha^{-1}$ + 658 $kgKha^{-1}$) as the optimum. This report is further certifying the need of new fertilizer practice when adopting an increase of planting density from 1667 $plants.ha^{-1}$ to 2500 $plants.ha^{-1}$ as the nutrient requirement may have changed (Husameldin and Mohammed, 2014). Actually, 40 $kgNha^{-1}$ and 110 $kgKha^{-1}$ were added respectively for an increase of 833 plants corresponding to 40 g of N against 132 g of K when reported by plant in the line with the suitable rating of banana fertilizer recommendation (Lassoudière *et al.*, 1978) and showing prevalence of K while N was the most required nutrient in high planting density of crops (Asim *et al.*, 2013). However, normal growth of plantain requires balanced ratio of N: K (1:1) in plant tissue underling low efficiency of K nutrition. Although this analysis is not innovative, it may have great importance in forest agro-ecosystems of West Africa characterized by soil phosphorus immobilization (Yadav and Dadarwal, 1997; Glass, 1989 ; Koné *et al.*, 2014b) and P-fertilizer efficiency might be strongly depending to nitrogen and potassium interaction (Turner, 1987). Well, it was established an increasing of P-requirement by plant with the increasing of K rates and uptake (Turner and Barkus, 1983). Therefore, P deficiency was likely to be increase under practice during the current study with constant rate of P (30 gP/plant) indifferently to the treatments. Nevertheless, there may be more suitable interaction of N ×P ×K in the treatment T2 than the others somewhat impaired by P-rate in the manner to limit the plant response to the applied fertilizer. Therefore, further study should increase P-fertilizer rate as 37.5 g/plant (94 $kgha^{-1}$) calculated in the basis of T2 to meet the plant requirement.

Such adjustment might be a driver of increasing K efficiency which is major fact for banana physiology, especially for hormonal activities and the regulation of water requirement (Ng Kee kwong *et al.*, 1994) so sensitive for the success of such current investigation.

4.3. Mineral and Water nutrition

The hand and finger numbers of banana were not impacted with difference between treatments during each of the cropping cycles while the treatments T4 and T5 as the greatest fertilizer rates have often induced significant increase of these parameters from the first to the second cropping cycle. These results denote the limited sensitivity of these parameters to the applied fertilizer when emphasizing discriminating importance of the mineral and water interaction as often observed in limited water supplying agrosystems (Koné *et al.*, 2008): Beside the constant numbers observed for lowest treatments, these parameters were lower during the first cropping cycle for greatest rates of fertilizer (T4 and T5) coinciding with the poorest rainfall (1050 mm ≠ 1858 mm) of 2013. Hence, only the heaviest fertilizer rates were concerned by the water shortage impacting negatively the numbers of hand and finger. Off course, this is not strange in agrosystems as referring to the haying-off concept related to the effect of nitrogen heavy rates observed on crops growing in limited water supplying condition (Cantero-Martinez *et al*. 1995; Van Herwaarden, 1996).

In turn, the girth of finger was likely more sensitive to different treatment effects indicating this parameters as the preferential target yield component when improving the yield of plantain using fertilizer in contrast with the number of finger which may be specific to genotype (Boyé *et al.*, 2010). Moreover, this preferential yield parameter was consistent across cropping cycles under different treatment effects. Meanwhile, bunch weight reduction was occurring indifferently to the treatments as consequence of continuous cropping which may involve biotic and abiotic stress (Lassoudière, 2007).

4.4. Sustainability of high planting density agrosystem

The soil of the studied site was roughly characterized by suitable chemical fertility with a low acidity allowing availability of a wide spectrum of nutrients including micronutrients (S, Mn, Fe and Zn) also required by growing plantain (Lahav *et al.*, 1978) and the rate of mineralization of the organic matter is moderate in the manner to slow down nitrogen loss (Probert *et al.*, 2004). In turn, unbalanced ratio of Ca: Mg (< 3:1) observed in 20 – 40 cm depth is likely to inhibit phosphorus uptake by plant (Yates, 1964 ; Koné *et al.*, 2009) in spite of the moderate content in soil while the ratio of K/ECC (≤ 3%) was accounting for K deficiency. Of this analysis, soil fertility management in the studied agro-ecology should be more focused on P and K for sustaining plantain cropping as suspected in previous section.

The mean value of bunch weight was ranging between 12 – 14 kg per plant as about 78 $kgNha^{-1}$, 39 $kgPha^{-1}$ and 75 $kgKha^{-1}$ of nutrient exportations only by the fruit when referring to the standard minimum concentrations in banana tissue (Renter and Robinson, 1986). Supposing that the fruit is representing only 1/3 of the total biomass during a cropping cycle, the plantain will remove 234 $kgNha^{-1}$, 117 $kgPha^{-1}$ and 225 $kgKha^{-1}$ denoting a low rate of P (75 $kgPha^{-1}$) as applied during the study while excess of K (548 – 822 $kgha^{-1}$) was observed.

This analysis is buttressing the depressive effect of the treatments on the bunch weight, especially, for the heaviest rates of N and K in T3, T4 and T5 characterized by excess of K respectively. Well, this excess is known to have antagonistic effect with the uptake of Ca and Mg (Lahav et al., 1978) which are involved in the nutrition of P, yet characterized by increasing deficiency across cropping cycles. Thereby, unbalanced ratio of N: P tightly involved in mineral nutrition of banana (Lahav *et al.*, 1978) should be pronounced for heaviest treatments reducing the bunch weight as already reported by other authors (Lahav, 1972 ; Al-Harthi et Al-Yahyai, 2009). Nevertheless, contrasting results were also observed when referring to the work of Nankinga *et al.*, (2005) conducted in Ouganda. Therefore, specific site management of N and K nutritions (Bationo et al., 2007) should be explored for deepening knowledge of plantain fertilizer management.

5. Conclusion

This study has revealed sound opportunity of practicing high planting density of banana applying 2500 plants/ha of the cultivar Corne 1. However, the response to fertilizer N×K was limited to T2 (240 kgha-1 of N and 658 kgha-1 of K) with more pronounced reduction of fruit production (12 – 14 kg/plant) according to supplemental fertilizer rates coupled with agro-morphological parameters annual depreciation.

Applying low irrigation and P-fertilizer (< 37.5 g/plant) rates, a low efficiency of K nutrition as well as a potential unbalanced ratio of N: P were justifying the results.

It was recommended the rates of 240 $kgNha^{-1}$ and 658 $kgKha^{-1}$ for cropping Corne 1 applying high density of 2500 plants/ha unless improving the efficiency of K nutrition when applying 37.5 $gPha^{-1}$ and following suitable ratio of N: P on the basis of the treatment T2. The irrigation rate should be also concerned (> 20mm/week) for boosting the plant response to N×K fertilizers when improving the banana fruit production.

6. References

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